Report as of FY2010 for 2010PA124B: "Simultaneous Removal of Phosphorous and Organic Acids using Magnetic Ion Exchange Resin (MIEX) Treatment and Alum Prior to Micron Filtration"

Publications

- Articles in Refereed Scientific Journals:
  - Kim, Hyun-Chul; Brian A. Dempsey, 2010, Removal of organic acids from EfOM using anion exchange resins and consequent reduction of fouling in UF and MF, J. Membrane Science 364(2010), 325-330.

Report Follows

PROJECT TITLE & PRINCIPAL INVESTIGATORS

Simultaneous removal of phosphorous and organic acids using magnetic ion exchange resin (MIEX) treatment and alum prior to micron filtration

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PROBLEM & RESEARCH OBJECTIVES

The main goal was to achieve simultaneous removal of total phosphorus (TP) and membrane fouling natural organic matter (NOM) during wastewater treatment using magnetic ion exchange resin (MIEX).

MIEX is an alternative to biological nutrient removal (BNR) for decreasing TP. MIEX contains a quaternary amine cationic polymer adhered to Fe-oxide precipitates that are magnetic allowing rapid separation and recovery. BNR cannot consistently attain the TP goal of <0.3 mg/L without coagulants. Use of coagulants results in excess sludge production, high costs, and additional wastewater effluent discharge of sulfate and aluminum. Membrane treatment is also increasing in use since it provides positive removal of particles including pathogens and particulate P. We have shown that MIEX is effective in removing the NOM constituents that cause membrane fouling.

Thus the research objectives were the following: (1) determine the effects of competing anions and NOM on the removal of TP from wastewater effluent organic matter (EfOM); (2) identify the removals of TP using several treatment modes; and (3) find the best methods for administering MIEX in a treatment facility, especially considering column operation or addition during rapid-mix with subsequent sedimentation (or not) prior to passage of the wastewater through low-pressure membrane filters.

METHODOLOGY

Experiments were all performed at bench-scale using column and jar-testing operations followed by membrane filtration. In Phase 1 the independent variables were MIEX concentration, EfOM concentration, anion concentrations (nitrate and sulfate), NOM concentration, TP, pH. In Phase 2 both complete-mix and fixed-bed column were investigated with results monitored by water quality, resistance to filtration, and flux recovery with cleaning. In Phase 3 the MIEX and membrane treatment processes were optimized for removal of TP and reduction in membrane fouling.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Batch tests for removal of TP and fouling using MIEX, IRA-958, or coagulants. This phase of the project was designed to identify the feasibility for applying MIEX and other strategies for simultaneous removal of TP and membrane foulants from wastewater effluent.

1. MIEX removal of membrane foulants was not affects by the anions bicarbonate, phosphate, nitrate, and sulfate.

2. MIEX removal of TP in batch tests was adversely affected by higher concentrations of sulfate and alkalinity.
3. MIEX removal of TP was not affected by lower molecular-weight (MW) EfOM organic acids but was adversely affected by high MW alginates that are a constituent ofn some wastewaters.
4. IRA-958 removal of TP was not affected by sulfate or alkalinity.
5. Aluminum chlorohydrate (ACH) coagulant removal of TP was adversely affected by alginates but not by lo MX EfOM organic acids.
6. IRA-958 removal of alginates was increased in the presence of higher alkalinity, while MIEX removal of alginates was not affected by alkalinity.
7. In the absence of high sulfate, alkalinity, or alginate, MIEX was more effective than IRA-958 for removal of both TP and membrane foulants despite smaller charge capacity of MIEX.
8. The batch experiments demonstrated that MIEX or other anion exchange resins could effectively remove both TP and membrane foulants for some conditions.

Column studies. This phase of the work was designed to evaluate the effectiveness of cationic exchange resins under the best possible conditions, passage through a bed of resin as opposed to the cheaper alternative of directly adding resin into a flowing stream.

1. Passage of wastewater effluent through a fixed-bed column of MIEX resulted in nearly complete elimination of short-term fouling of PVDF MF and PES UF membranes, even for permeate flux exceeding 300 $Lm^{-2}hr^{-1}$ which is up to an order of magnitude higher flux than typically used. Thus the cost of installing and operating a bed of resin could be partially offset by the increased loading and decreased capital and operating costs for operating membrane filters.
2. The reduced fouling coincided with nearly complete removal of particles, colloids, and HPO/HPI organic acids. MIEX in fixed-bed form also removed >50% or HPO base/neutrals, less than a third of TPI base/neutrals, and no HPI base/neutrals. This means that the quality of filtered water (with respect to organic content) would be significantly superior if a bed of MIEX resin were used ahead of the membranes.
3. The removal of TP from wastewater effluent from University Area Joint Authority (UAJA) was much greater than predicted from batch tests of synthetic waters (reported above) or from batch tests of UAJA water. This is particularly significant because UAJA uses alum as a coagulant thus adding high sulfate concentration to the wastewater.
4. The resin capacity for TP and membrane foulants was simultaneously exhausted. This would result in more efficient and cost-effective operation of a column of resin.
5. MIEX was more effective than other resins for simultaneous removal of TP and membrane foulants.

Rapid-mix addition of MIEX. MIEX can be added directly to the wastewater stream resulting in decreased capital costs and perhaps in decreased operating costs. Treatment options that were considered included direct addition of MIEX without intermediate removal by sedimentation resulting in accumulation on the membrane surface, addition of MIEX followed by

sedimentation so that most of the MIEX did not accumulate o the membrane surface, and addition of MIEX with simultaneous addition

1. Complete-mix additions of MIEX, alum, or MIEX/alum reduced TP and membrane fouling but to a lesser extent than for fixed-bed MIEX.
2. There was also poorer removal of particles, colloids, and HPO/HPI acids compared to fixed-bed MIEX.
3. The best combination for simultaneous removal of TP and EfOM after complete mix used 15 mL/L of MIEX and only 1 mg/L of Al.
4. Complete-mix additions of MIEX with simultaneous low coagulant doses and membrane filtration resulted in permeate TP < 0.3 mg/L.
5. These results indicate that fixed-bed or fluidized-bed operation of MIEX ahead of MF or UF should be considered for full-scale treatment.

The results demonstrate that MIEX or other anion-exchange resin can be used in combination with other TP removal strategies, resulting in lower discharge concentrations and greater reliability for compliance with TP goals. The simultaneous decrease in fouling of low-pressure membranes could result in increased permeate fluxes and decreased cost for construction and operation of membrane systems.

STUDENTS & POSTDOCS SUPPORTED

Masters students

Robbie Wolford (expected graduation as M.S. in Env. Eng., August 2011)

Xia Shang (expected graduation as M.S. in Env. Eng., December 2011)

Post-Doc

Hyunchul Kim